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The purpose of this experiment was to assess the effects of a variable-interval changeover contingency on both main-key and CO-key behavior. This contingency was varied from 5 to 160 sec. The major concern was whether response and time matching would occur as has been reported to occur when a changeover delay is varied. Like the changeover delay, varying the variable-interval changeover contingency produced a decrease in the CO rate; however, unlike the COD, large deviations from matching occurred. When the response and time distributions were recomputed so as to include the CO-key behavior, more of the response and time distribution points fell within the matching range. The role of CO contingencies in concurrent schedules was considered.

Since the present procedure has certain formal similarities to a CO-key concurrent chains schedule, it was of interest to determine if the relative response rates on the CO-key would match the relative rates of reinforcement on the main-key. Such matching did not occur. Differences in programming between the present procedure and the usual two-key procedure were discussed.

THE EFFECTS OF A VARIABLE-INTERVAL CHANGEOVER CONTINGENCY ON CONCURRENT PERFORMANCES

by

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CHAPTER I

INTRODUCTION

A concurrent schedule of reinforcement arranges reinforcement to be provided by two or more independent, simultaneously available schedules, each associated with a different exteroceptive stimulus. One programming method, called the two-key procedure, consists of programming each schedule on a separate key. Each time a switch is made from one key to the other, a changeover (CO) is said to occur. Another programming method, the changeover key procedure (Findley, 1958), consists of programming both schedules on a single key, called the main-key, and responses on a second key, called the CO-key, alternate the main-key stimulus and its associated schedule. In either method, four operants may be identified in any two concurrent schedules: the operants for the two different main-key schedules and the two CO operants to the two different main-key schedules. While the two programming methods appear to be equivalent (Catania, 1966), the CO-key procedure makes the two CO operants more explicit.

Much of the research dealing with concurrent schedules has involved determining how the distribution of concurrent operants is affected by various reinforcement parameters, most notably, rate of reinforcement. Herrnstein (1961)

examined the effect of rate of reinforcement on concurrent operants and found that alternation between the two schedules was so frequent that most of the responses that were emitted were CO operants. The use of a changeover delay (COD), which specifies a minimum time before a response occurring after a CO can be reinforced, functioned to reduce the frequency of the CO operants and the resulting relationship was that the relative number of responses emitted on a key was proportional to the relative number of reinforcements for that key.

The high frequency of CO operants that occurs without the use of a COD has been assumed (Herrnstein, 1961, 1970; Catania, 1963) to be due to concurrent superstition; that is, because a response on one key is often followed by a reinforced response on the other key, the reinforcement strengthens not only responding on the key providing reinforcement, but also strengthens the CO response, thereby generating rapid alternation. The COD, then, by imposing a temporal delay between responses on one key and reinforced responses on the other key, presumably eliminates concurrent superstition by preventing the correlation between a CO response and reinforcement, and thereby allows the response distribution to match the reinforcement distribution. According to this analysis, once a minimum COD value is attained that will reduce alternation sufficiently to

produce matching, then matching should occur at all higher COD values.

The effects of a range of COD values ranging from 0 to 20 secs on both relative response distributions and CO rate was examined by Shull and Pliskoff (1967). They found that the CO rate was a decreasing function of COD value, and that the relative response rates were an increasing function of the COD with matching appearing to be only a range of points on the continuous function. However, because of the increasing relative time distribution, the obtained reinforcement rates increasingly deviated from the scheduled reinforcement rates, and in such a manner that matching did occur with respect to obtained reinforcement rates. Herrnstein (1970) and Rachlin (1971) have argued that matching is always with respect to obtained rather than scheduled reinforcements. Matching of relative responses to relative scheduled reinforcement rate across COD values from 0 to 32 secs has been demonstrated by Stubbs and Pliskoff (1969) under conditions that ensured that the obtained reinforcement rates equalled the scheduled reinforcement rates.

Nevertheless, the manner in which the COD functions to generate matching has been shown by Silberberg and Fantino (1970) to be very complex. They found that the response rates during the COD were much higher than after the COD and that the relative response distribution during the COD was a decreasing function of the relative reinforcement

distribution, and the post-COD relative response distribution was an increasing, but non-proportional, function of the relative reinforcement distribution. Though neither of these separate response distributions matched the reinforcement distributions, the two rates, nevertheless, averaged so as to produce matching.

Because matching results from an interaction of the COD with the main-key operants, it does not appear, then, to be a general relationship that emerges once the changeover operants are sufficiently reduced. Yet, it might still be considered a general law that is based upon an interaction of main-key operants with the COD. The generality of matching, then, would require that any contingency placed upon the CO operants which results in a decrease in CO rate would interact with the main-key operants in a manner so as to produce matching across a wide range of parameters. The nature of the relation between response and reinforcement distributions has, in fact, been examined when COs are reduced by methods other than a COD. These include Fixed-ratio (Stubbs and Pliskoff, 1969; Brownstein, et al., 1972), shock (Todorov, 1971) and time-out (Todorov, 1971). Like the COD, CO frequency is a decreasing function of each of these contingencies. Yet, their effects upon main-key behavior appear to be different from the COD. Like the COD, a certain minimal value is necessary in order to generate matching, but, while matching continues to

occur at higher COD parameters, with these other contingencies deviation from matching occurs. The generality of a relation which can be demonstrated only under a restricted set of parameters would appear to be questionable. While a CO contingency was initially conceived of as a procedure that merely reduces COs, thereby allowing matching of main-key operants to occur, the CO contingency clearly interacts with the main-key operants in such a manner that the relationship between relative response distributions and relative reinforcement distributions cannot be stated independently of the CO procedure or its value.

In an attempt at further exploring the effect of CO contingencies on both the CO operants and the main-key operants, the present experiment imposed a variable-interval requirement on the changeover response. This procedure is similar to a COD in that it imposes a temporal delay between responding on one schedule and reinforcement on the other schedule; however, like the FR, shock and TO procedures, the contingency placed on the CO response is explicitly separated from the behavior controlled by the main-key contingencies. The CO VI differs from all the other CO contingencies in that it is a variable contingency. In addition, it permits a direct measure of response rate of the CO operants while the CO is occurring, thus, making it possible to determine if the response rates on the CO-key

would be differential with respect to the main-key schedule to which a CO was being made.

CHAPTER II

METHOD

Subjects

Four White Carneaux pigeons were maintained at 80% of their free-feeding weights. Each bird had had previous experience with concurrent schedules.

Apparatus

A standard Lehigh Valley two-key pigeon chamber was used. White noise masked extraneous sounds. Reinforcement consisted of four seconds access to grain. All procedures were controlled automatically by standard electromechanical equipment. Data were recorded by counters, elapsed time meters and a cumulative recorder.

Procedure

The experiment used the CO-key procedure of concurrent schedules described by Findley (1958). The right key was transilluminated either red or green and the left key white. Reinforcements were programmed by a single VI 0.75-min schedule and a stepping switch assigned 70% of the reinforcements to the green color and 30% to the red color so that functionally a Concurrent VI 1.07-min VI 2.50-min schedule was in effect. To ensure that the programmed reinforcement distribution equalled the obtained reinforcement

distributions, reinforcement assigned to one main-key color had to be obtained in that color before the next reinforcement was programmed.

FR 1 Baseline. In the first phase of the experiment a single peck on the white CO-key changed the color on the main-key and darkened the CO-key. Pecks on the CO-key were ineffective when it was dark. The first response on the main-key reilluminated the CO-key. Since only a single peck was required for a CO, this condition is designated the FR 1 baseline condition.

Phase II. In the second phase of the experiment, the CO contingency was changed from a single peck to a variable-interval schedule referred to as the CO VI schedule. This contingency required that a VI requirement be fulfilled on the CO-key in order to gain access from one main-key schedule to another. The first peck on the CO-key started the CO VI schedule, turned off the main-key light and stopped the main-key schedule so that the birds would not switch between the CO-key and the main-key before the CO VI schedule was completed. The first peck on the CO-key after the CO VI elapsed changed the main-key color from the color prior to the CO. It also started the main-key schedule again and darkened the CO-key. This procedure totally separated the behavior during the CO contingency from the behavior after the CO contingency.

Phase III. The CO VI contingency differs from other CO contingencies that have been used in that it is a variable contingency. In order to determine if CO contingencies that are variable have different effects from CO contingencies that are fixed, in the third phase of the experiment an FI CO contingency was used which had the harmonic mean of the CO VI 5-sec schedule. This value of the FI was 3.5 sec. The harmonic mean rather than arithmetic mean was used since Killeen (1968) showed in concurrent chain schedules with a VI in one terminal link and an FI in the other terminal link that matching was respect to harmonic rates of reinforcement rather than arithmetic rates of reinforcement. The FI CO was programmed exactly like the VI CO except that the interval was constant.

Phase IV. When the CO VI was varied from 5 sec to 160 sec, the relative response rate that occurred on the CO-key during the CO did not deviate appreciably from 0.50. In order to make the CO to the separate schedules more discriminable, the illumination of the CO-key was changed so that the color was different depending upon the main-key schedule to which a CO was being made. While either main-key was lighted, the CO-key was white, but the first response on the CO-key not only darkened the main-key but also changed the CO-key to blue if the CO was to red and to amber if the CO was to green. The first response on the CO-key after the CO VI elapsed, darkened the CO-key and

lighted the main-key. The first response on the main-key reilluminated the CO-key with white. In this phase, a CO VI 40-sec and a CO VI 80-sec schedule was used.

The sessions were run daily. Each bird received 60 reinforcements a session except C-5 who received 50. Each experimental condition was run until there appeared to be no systematic trends in the data. Table 1 indicates the sequence and the number of sessions of the experimental conditions. The entries under the columns entitled Main-key Responses, Main-key Time, COs, CO-key Responses and CO-key Time are averages over the last five sessions of each experimental condition. The VI 5-sec (R) condition is a recovery of the VI 5-sec condition. The VI 40-sec (A-B) and VI 80-sec (A-B) conditions constitute Phase IV where the CO-key was transilluminated either amber or blue during the CO.

Table 1. Summary of Data for Each Condition

CO Requirement	Main-key Responses		Main-key Time(min)		COs	CO-key Responses		CO-key Time(min)		Sessions
	Red	Green	Red	Green		To Red	To Green	To Red	To Green	
Bird C-4										
FR 1	362	921	12.75	30.46	422					30
VI 15-sec	455	1420	15.16	40.12	50	495	466	6.76	7.05	25
VI 10-sec	269	1477	12.52	43.94	62	371	359	5.95	6.01	34
VI 5-sec	288	1607	14.93	35.18	88	558	562	5.42	5.83	72
VI 40-sec	255	2291	14.79	52.84	41	365	369	12.73	13.83	53
VI 80-sec	419	2507	15.40	51.13	33	481	453	20.84	17.64	48
VI 160-sec	53	2821	27.44	80.15	42	1273	1261	39.38	49.44	124
VI 5-sec(R)	50	1391	8.96	45.07	93	501	495	5.09	5.25	56
FI 3.5-sec	64	1390	6.86	46.01	90	444	386	3.50	3.36	40
VI 40-sec(A-B)	212	1455	14.24	46.59	49	615	320	17.13	15.72	101
VI 80-sec(A-B)	250	2073	11.11	58.70	41	1002	1016	38.52	36.45	41
Bird C-5										
FR 1	683	999	11.70	19.84	1258					30
VI 15-sec	248	3081	5.58	50.55	41	422	404	5.89	5.51	25
VI 10-sec	277	2228	7.87	40.62	55	524	465	5.20	5.28	34
VI 5-sec	259	2123	5.59	40.11	61	565	506	4.00	3.88	100
VI 40-sec	737	2315	21.19	39.88	22	564	441	8.88	8.96	55
VI 80-sec	81	2540	7.22	63.15	32	848	862	18.74	15.46	119
VI 160-sec	65	3624	7.28	75.32	33	1060	1166	35.38	35.01	34
VI 5-sec(R)	76	2215	7.29	41.62	62	270	349	3.15	3.83	56
FI 3.5-sec	173	2163	6.18	35.23	83	420	376	3.17	3.19	40
VI 40-sec(A-B)	130	3840	8.27	68.57	32	578	555	10.28	10.19	164
VI 80-sec(A-B)	46	3613	4.29	67.14	30	1276	1356	26.91	26.57	41

Table 1 (continued)

CO Requirement	Main-key Responses		Main-key Time(min)		COs	CO-key Responses		CO-key Time(min)		Sessions
	Red	Green	Red	Green		To Red	To Green	To Red	To Green	
Bird C-6										
FR 1	649	1326	12.25	26.68	1113					30
VI 15-sec	556	3145	11.14	39.71	80	751	754	10.48	11.70	25
VI 10-sec	454	3486	10.65	42.47	86	842	799	8.10	8.10	34
VI 5-sec	209	3440	6.23	43.31	92	520	447	5.73	5.13	72
VI 40-sec	1010	4118	16.23	47.01	41	899	812	13.14	11.27	49
VI 80-sec	1389	4529	18.56	49.69	37	1489	943	26.09	21.98	53
VI 160-sec	421	5066	10.05	65.78	40	3067	2937	37.71	44.14	109
VI 5-sec(R)	304	3559	8.46	48.69	128	833	776	6.75	6.43	37
FI 3.5-sec	303	3427	8.60	41.32	126	667	645	4.70	4.72	40
VI 40-sec(A-B)	372	4171	7.08	64.08	43	1154	1093	13.61	13.92	164
VI 80-sec(A-B)	335	5303	8.45	64.16	37	2199	2452	30.22	36.37	41
Bird C-7										
FR 1	600	1450	10.76	29.49	909					30
VI 15-sec	196	3222	11.44	44.28	56	814	752	7.87	7.06	25
VI 10-sec	224	2578	11.99	47.77	60	708	609	6.29	5.58	70
VI 5-sec	305	2590	12.88	38.96	80	514	595	4.62	5.19	35
VI 40-sec	472	5219	13.51	56.32	37	1147	1122	11.98	11.82	49
VI 80-sec	349	4671	10.83	70.14	31	1216	1031	21.59	26.47	53
VI 160-sec	142	3899	7.45	68.52	43	1867	2004	46.33	47.14	136
VI 5-sec(R)	188	2762	12.88	38.96	110	428	508	6.27	6.06	50
FI 3.5-sec	210	2403	9.20	40.94	130	401	417	5.37	4.96	40
VI 40-sec(A-B)	140	3309	15.39	62.13	44	764	866	15.00	14.04	164
VI 80-sec(A-B)	128	5321	11.15	69.46	40	1578	2116	38.34	36.63	41

CHAPTER III

RESULTS

Separate timers and counters recorded the main-key behavior and the CO-key behavior. The main-key responses and time were recorded separately for the red and green colors, and the CO-key responses and time were recorded separately depending upon whether the CO was to red or to green. CO initiations were recorded separately from the responses made on the CO-key during the CO VI duration. The results are described in terms of the means of the last five days of each condition. Each figure depicts the data from all four phases of the experiment. At CO VI 5-sec, the unconnected filled circles represent redetermination points and the unconnected unfilled circles represent the CO FI 3.5-sec points. At CO VI 40-sec and 80-sec, the unconnected unfilled points represent data from Phase IV where the colors on the CO-key were changed.

Main-key measures

Figure 1 shows the main-key relative response distribution for the richer schedule as a function of the CO contingency. This measure was computed by dividing the main-key responses in green by the total main-key responses. When a single peck was required to CO, the relative response

FIGURE 1

RELATIVE RESPONSES

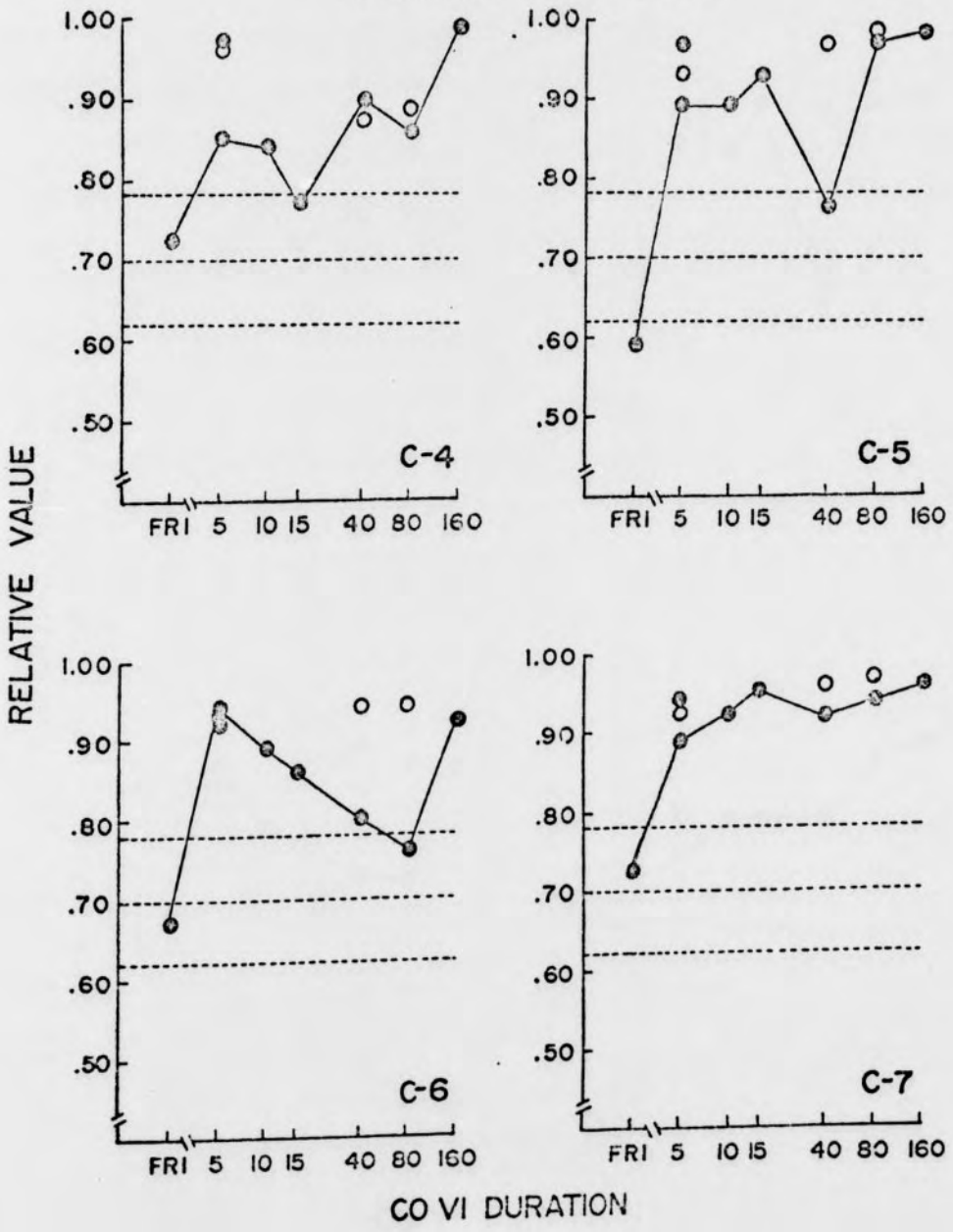
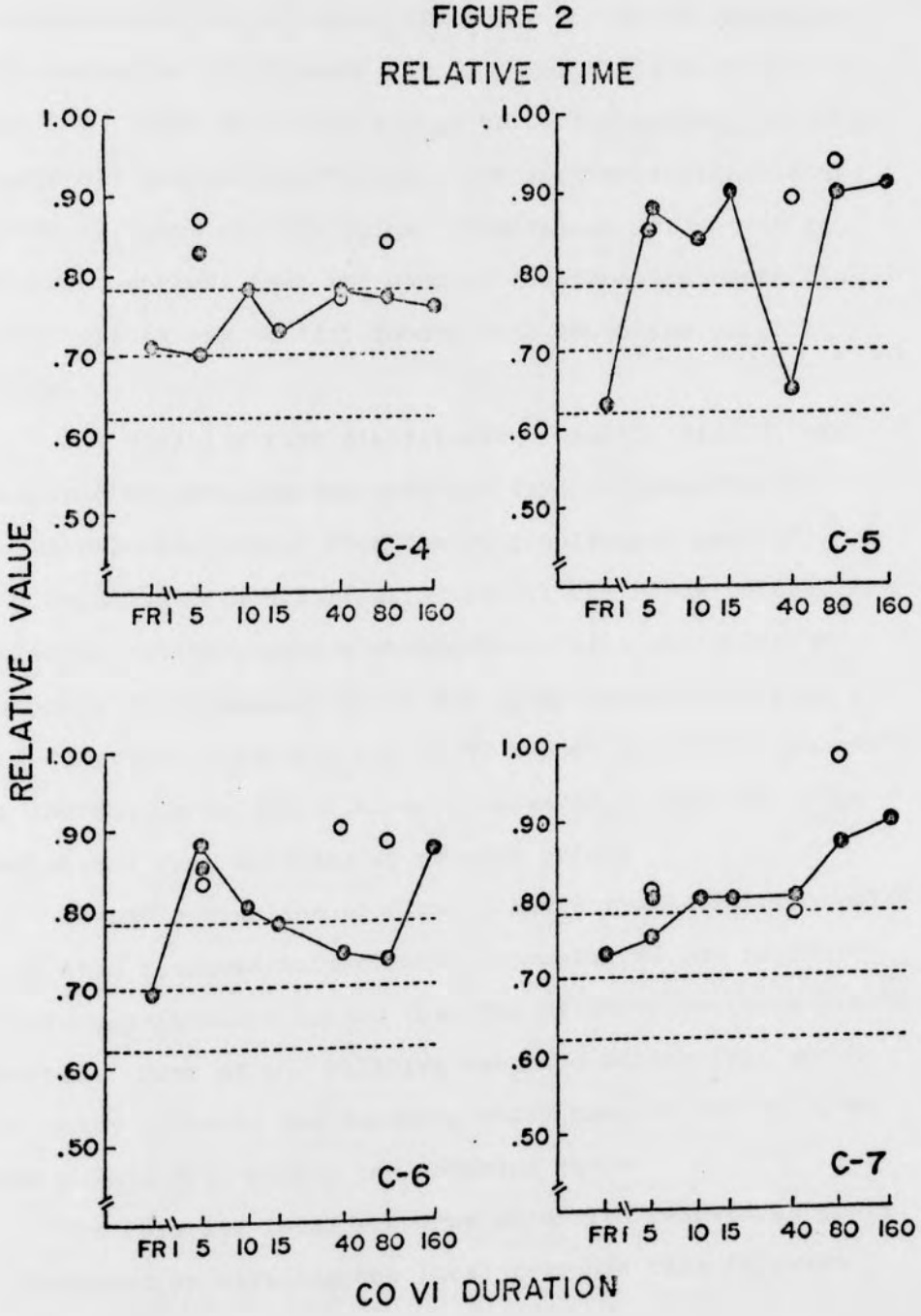


FIGURE 2


RELATIVE TIME
RELATIVE VALUE
1.00
.90
.80
.70
.60
.50
C-4
C-5
C-6
C-7
FR1 5 10 15 40 80 160
CO VI DURATION

distribution of three of the four birds matched the relative reinforcement distribution according to the 8% criterion for deviation (Herrnstein, 1961). For Birds C-4, C-5 and C-7, these functions appear to be increasing, although there are several inversions. The redetermination points at CO VI 5-sec and the points from Phases III and IV do, however, suggest that the part of the function containing CO VI values may be flat though well above the matching range.

The relative time distribution, seen in Fig. 2, was computed by dividing the main-key time in green by the total main-key time. When the CO requirement was FR 1, the relative time distribution of all the birds matched the relative reinforcement distribution. Like the relative response distribution, it is not clear whether the part of the function containing the CO VI values is better described as increasing or flat. Clearly, however, there are large deviations from matching at several points.

Visual comparison of Figs. 1 and 2 shows that the relative time measures more closely approximated the relative reinforcement distribution than the relative response distributions. Most of the relative response points fell above the upper criteria for matching while many of the relative time points fell within the matching range.

The relative local response rate with respect to green is computed by dividing the local response rate in green

by the sum of the local response rates in both red and green. The local response rates are computed by dividing the main-key responses in a given schedule by the main-key time in that schedule. Thus, if responding occurs at the same local rate in each schedule, the relative local response rate is 0.50. As depicted in Fig. 3, the relative local rate was approximately 0.50 for all birds when one peck was required to CO. With the exception of C-6 whose relative local rates were decreasing across most of the range of CO VI values, relative local response rates tended to increase across CO VI values. Computation of the local rates in each schedule, which may be made from Table 1, reveals that the local rates in green tend to increase as a function of the CO VI and the local rates in red tend to decrease as a function of the CO VI.

CO-key measures

Figures 4 and 5 show the rate of the two CO operants as a function of the CO VI. These rates reflect the frequency at which a bird changed out of a given schedule. The CO rate from green was computed by dividing the number of COs initiated while the main-key was green by the main-key time in green. The CO rate from red was computed by dividing the number of CO's initiated while the main-key was red by the main-key time in red. For each bird, both of these rates are decreasing functions of the CO VI, with the CO

FIGURE 3

RELATIVE LOCAL RESPONSE RATES

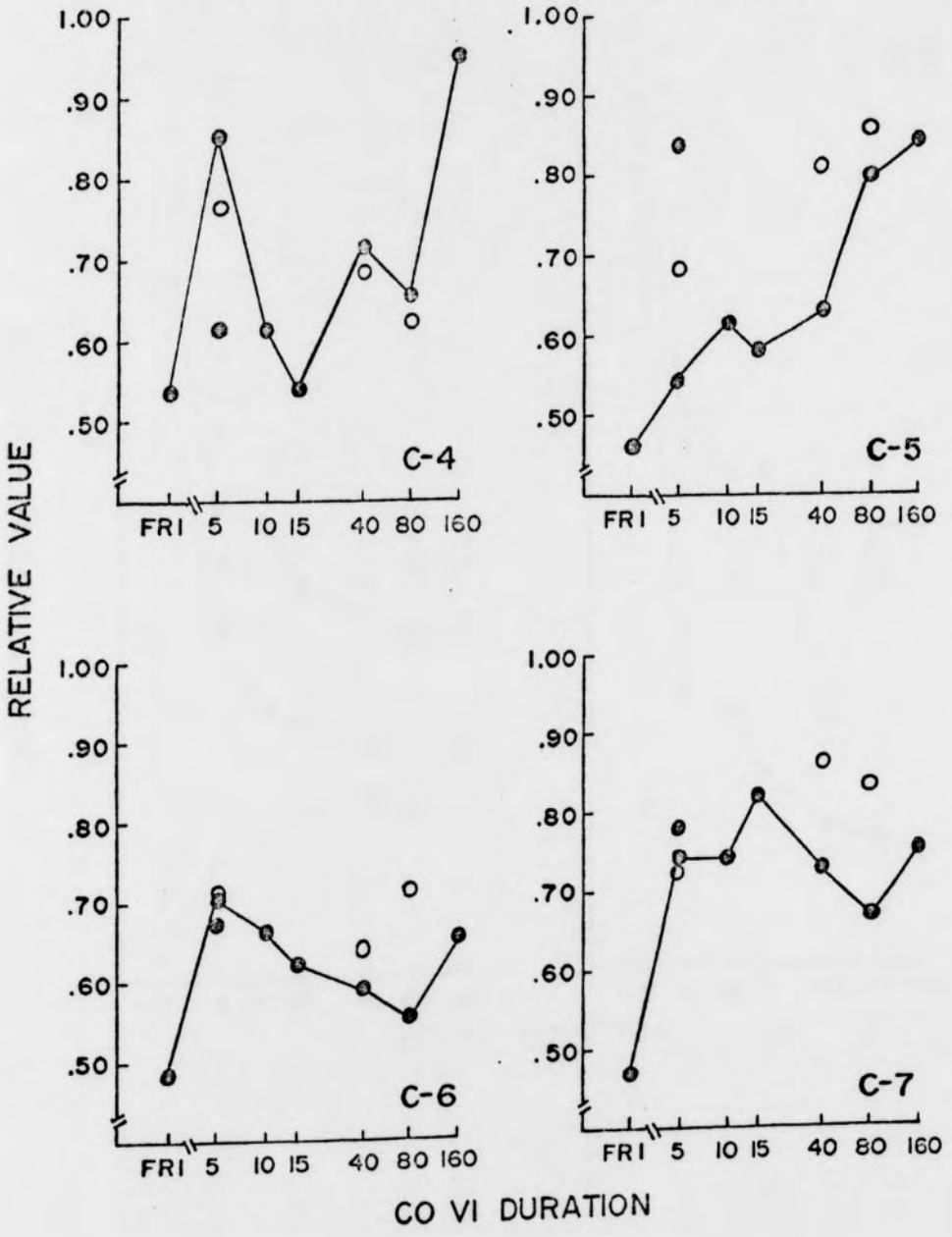


FIGURE 4

LOCAL CO RATES

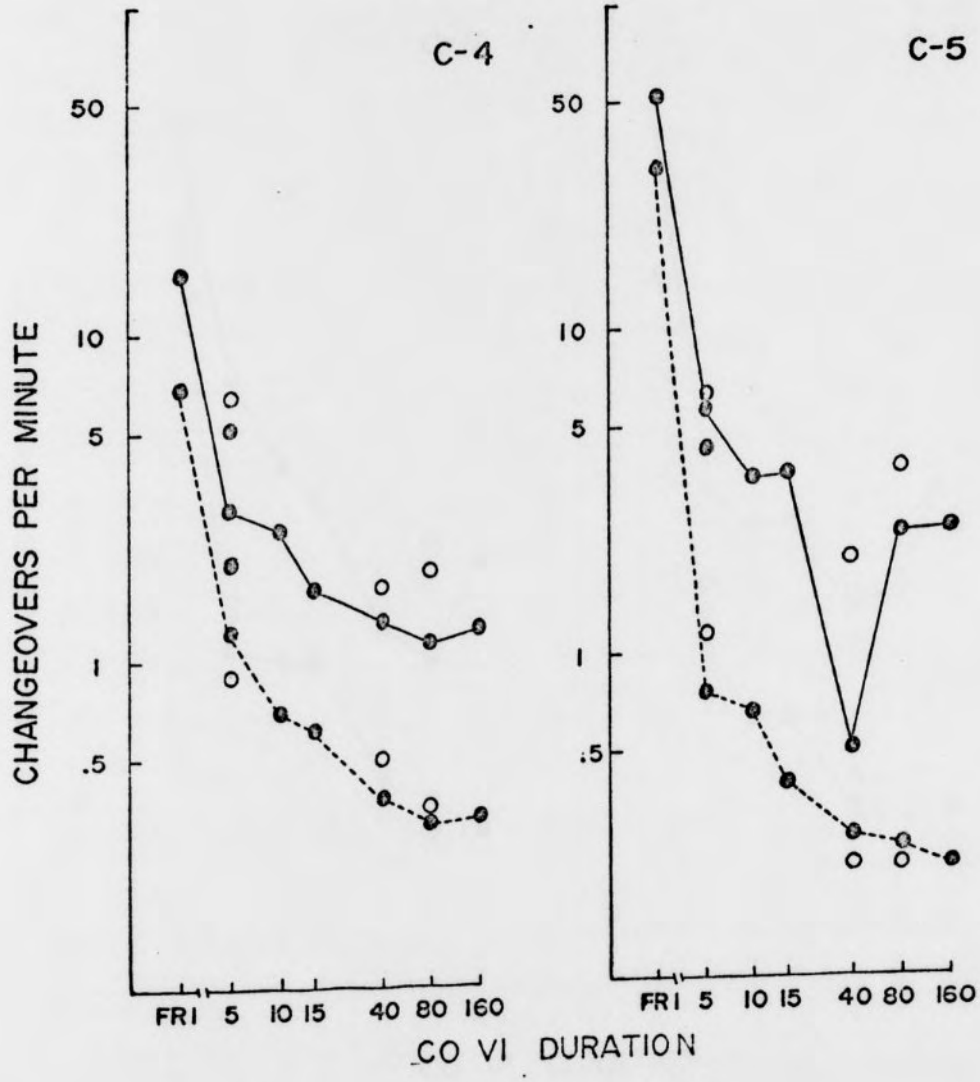
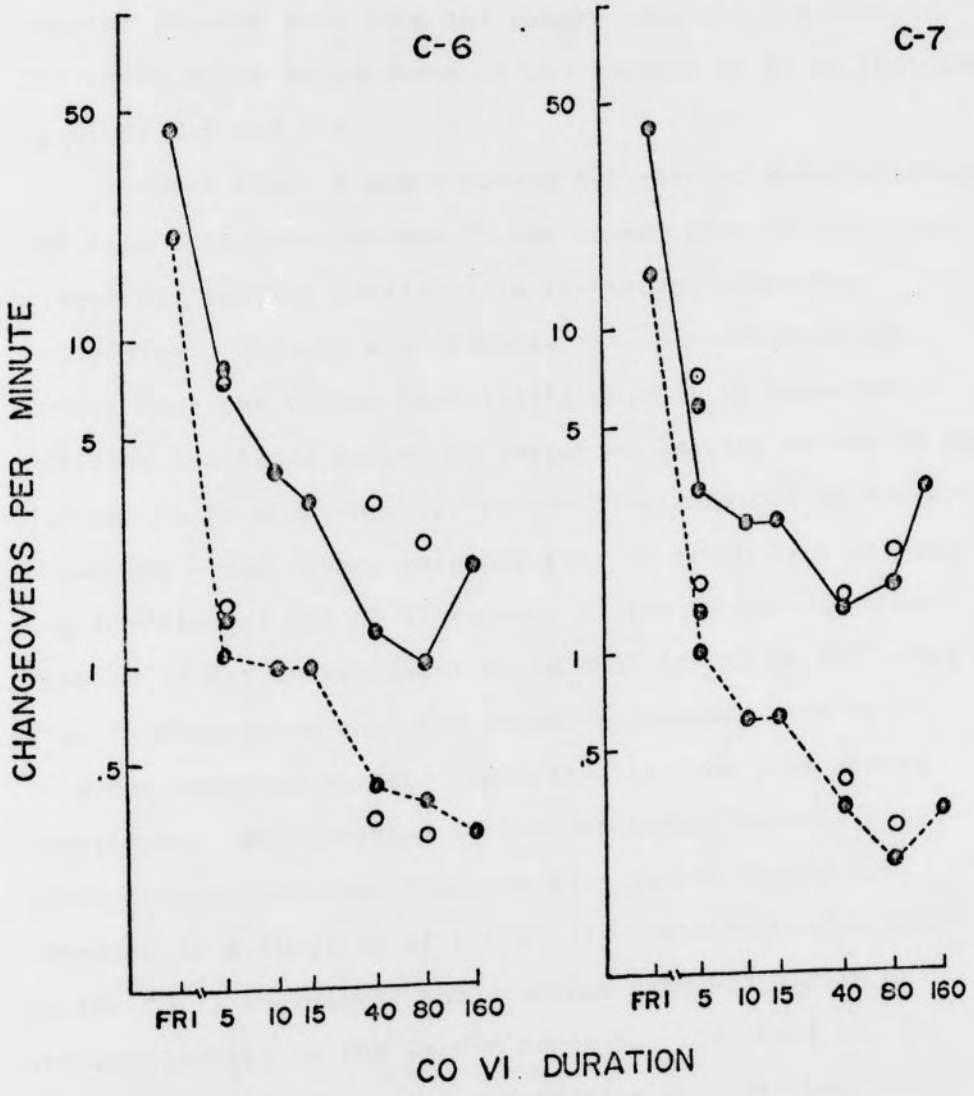


FIGURE 5

LOCAL CO RATES



rates from red being higher than the CO rates from green. Since green was the richer schedule, this indicated that the birds always changed from the leaner schedule with a shorter latency than from the richer schedule. A tendency for these rates to increase at the longest CO VI is indicated by Birds C-6 and C-7.

Whereas Figs. 4 and 5 showed the rate at which a change was made from one schedule to the other, Figs. 6 and 7 show a rate not usually available in concurrent schedules procedures. This is the response rate occurring on the CO-key once the CO has been initiated. It is computed by dividing the total number of responses emitted on the CO-key during COs to a given color by the time required to execute these COs. The CO-key response rate to green is a decreasing function of the CO VI value. A plot of the response rate to CO red is very similar to this one as is reflected in Fig. 7 which shows that the relative response rate to CO to green does not deviate significantly from 0.50 across conditions. An exception is C-6 for which there is a tendency for the relative response rate on the CO-key to decrease as a function of the CO VI. This indicates that as the CO VI increased, the response rate was higher on the key leading to the leaner schedule. In Phase IV, the color of the CO-key differed depending upon whether the CO was to red or to green. The open circles in Fig. 8 at CO VI 40-sec and 80-sec show that the effects of this

FIGURE 6

RESPONSE RATES ON CO-KEY

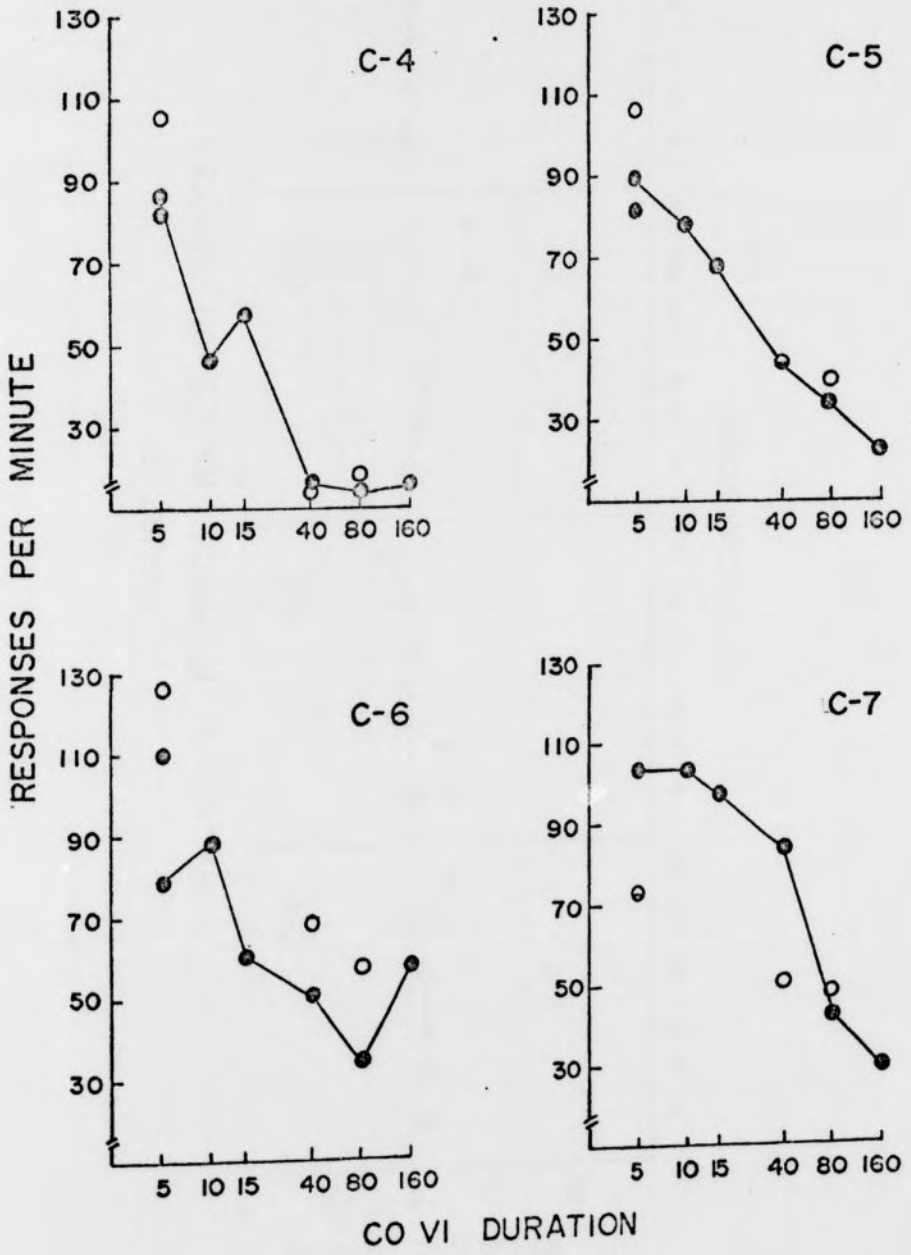
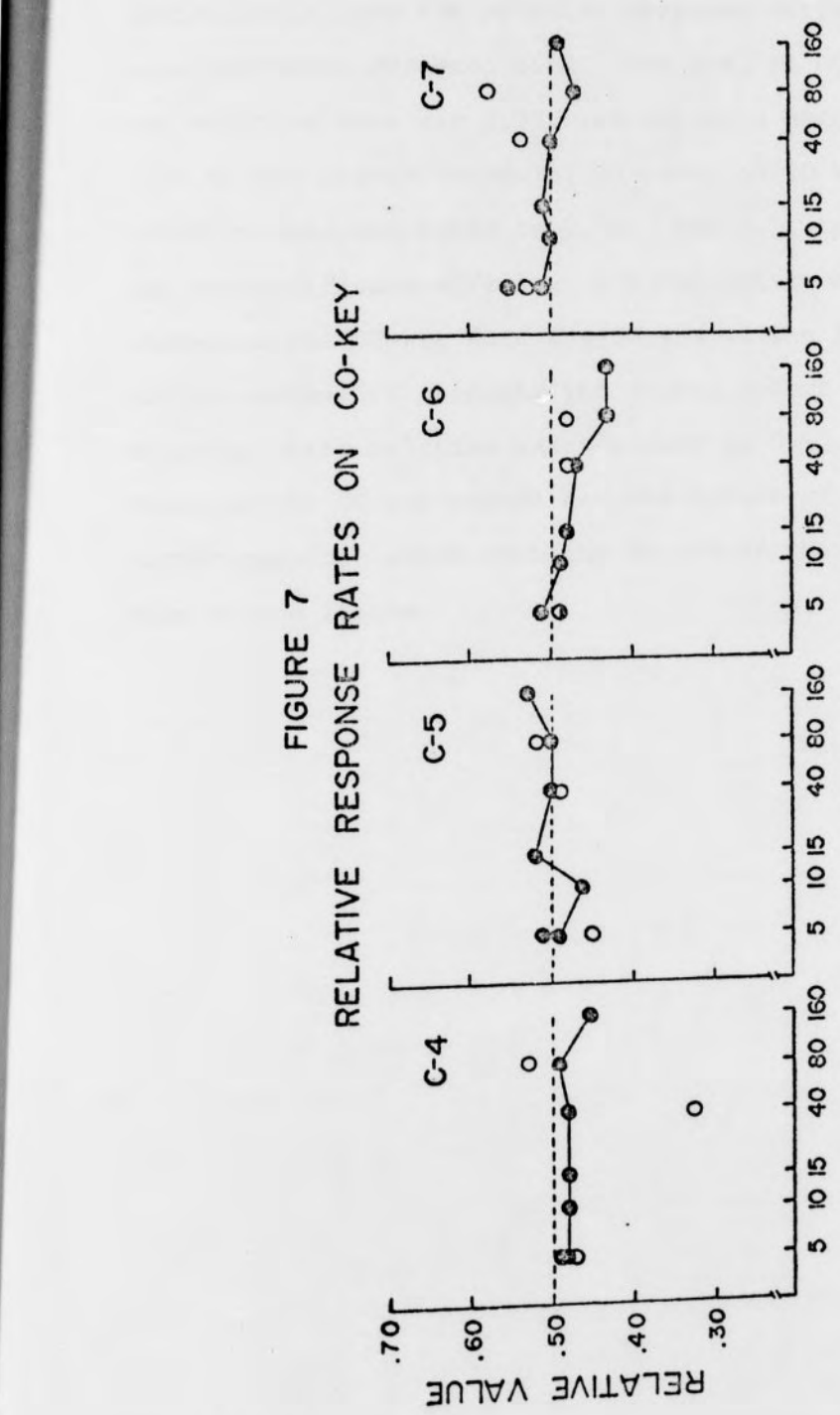


FIGURE 7

RELATIVE RESPONSE RATES ON CO-KEY



manipulation upon the relative response rates on the CO-key were different for each bird. For C-4, at CO VI 40-sec, the relative rate was 0.33, indicating a higher rate during a CO to the leaner schedule; however, at CO VI 80-sec, the relative rate was close to 0.50. For C-5, the manipulation had no significant effects. C-6 had previously responded higher on the CO-key when the CO was to the leaner schedule, but the effect of changing the CO-key colors was apparently to bring these relative rates closer to 0.50. For C-7, changing the CO-key colors had the effect of producing higher response rates when the CO was to the richer schedule than to the leaner.

CHAPTER IV

DISCUSSION

The purpose of this experiment was to assess the effects of a VI CO contingency on both main-key and CO-key behavior. The major measures of main-key behavior were the relative response distributions, the relative time distributions, and relative local response rates. The major measures of CO behavior were the rates of the two CO operants, and both the absolute and relative rates that occurred on the CO-key during the CO VI.

Before the CO VI was imposed, the relative time distributions approximated the relative reinforcement distribution within 8% for all of the four birds, and for three of the four birds, the relative time distributions approximated the relative reinforcement distribution within 8%. The effects of the CO VI on the dependent measures were as follows: (1) Though the effects were somewhat weak, both the relative response and relative time distributions tended to deviate continuously from the 0.70 matching line for three of the four birds. (2) The relative local response rates tended to deviate continuously from the 0.50 baseline for three of the four birds, although these effects were also somewhat weak. (3) Both of the CO rates decreased continuously as a function of the CO VI with the rate from the

lean schedule being higher than the rate from the richer schedule. (4) While the response rates on the CO-key during the CO VI decreased as a function of the CO VI, the relative rates did not deviate significantly from 0.50.

The deviation from matching across most of the range of CO VI values stands in contrast to the effect of varying a COD. Stubbs and Pliskoff (1969), using a similar procedure that ensured equivalance of programmed and obtained reinforcement rates, found matching to occur across a range of COD values from 0 to 32 sec. This discrepancy between the use of a COD and a CO VI may be more apparent than real. More explicitly, this discrepancy may be due to differences in the manner in which the relative time and relative response distributions are computed when these two CO contingencies are used. When a COD is used, calculation of these distributions includes the COD responses and time. This is not the case with the VI contingency where main-key and CO-key behavior are measured separately. Since Silberberg and Fantino have shown that with COD values in which matching occurs, the post-COD behavior is an increasing function of the reinforcement rate, this clearly indicates that whenever matching is observed with the use of a COD that over-matching is actually occurring when only the post-COD behavior is measured. This post-COD behavior is analogous in the present study to the main-key behavior since the behavior during the CO contingency is measured

separately on the CO-key. Brownstein et al. (1972), who imposed a FR contingency on COs, have shown that when the relative response and relative time distribution include the CO-key behavior, more of the FR points fell within the matching range than when these computations did not include the CO-key behavior. Figures 8 and 9 show the relative response and relative time distributions calculated so as to include the CO VI behavior. While many of the response distribution points are above matching, most of the time distribution points fall within the 8% range of matching. Thus, when the behavior during the CO VI contingency is considered part of the main-key behavior, as is the case with the COD, the CO VI produces matching across a much wider range of CO VI values. Over-matching has not been reported to have occurred when the COD has been varied; however, the longest COD employed has been 32 sec (Stubbs and Pliskoff, 1969) which is smaller than three of the CO VI values in the present study. Possibly, longer CODs would also generate over-matching. It may, however, be the case that the over-matching observed with the CO VI is due to the VI contingency and not merely the temporal delay it imposes.

The effects of a COD and CO VI can also be compared when the behavior during the CO contingency is not included. In this case, the range of CO contingency parameters which produces matching would be smaller in each case. When

FIGURE 8

MAIN-KEY AND CO-KEY RELATIVE RESPONSES

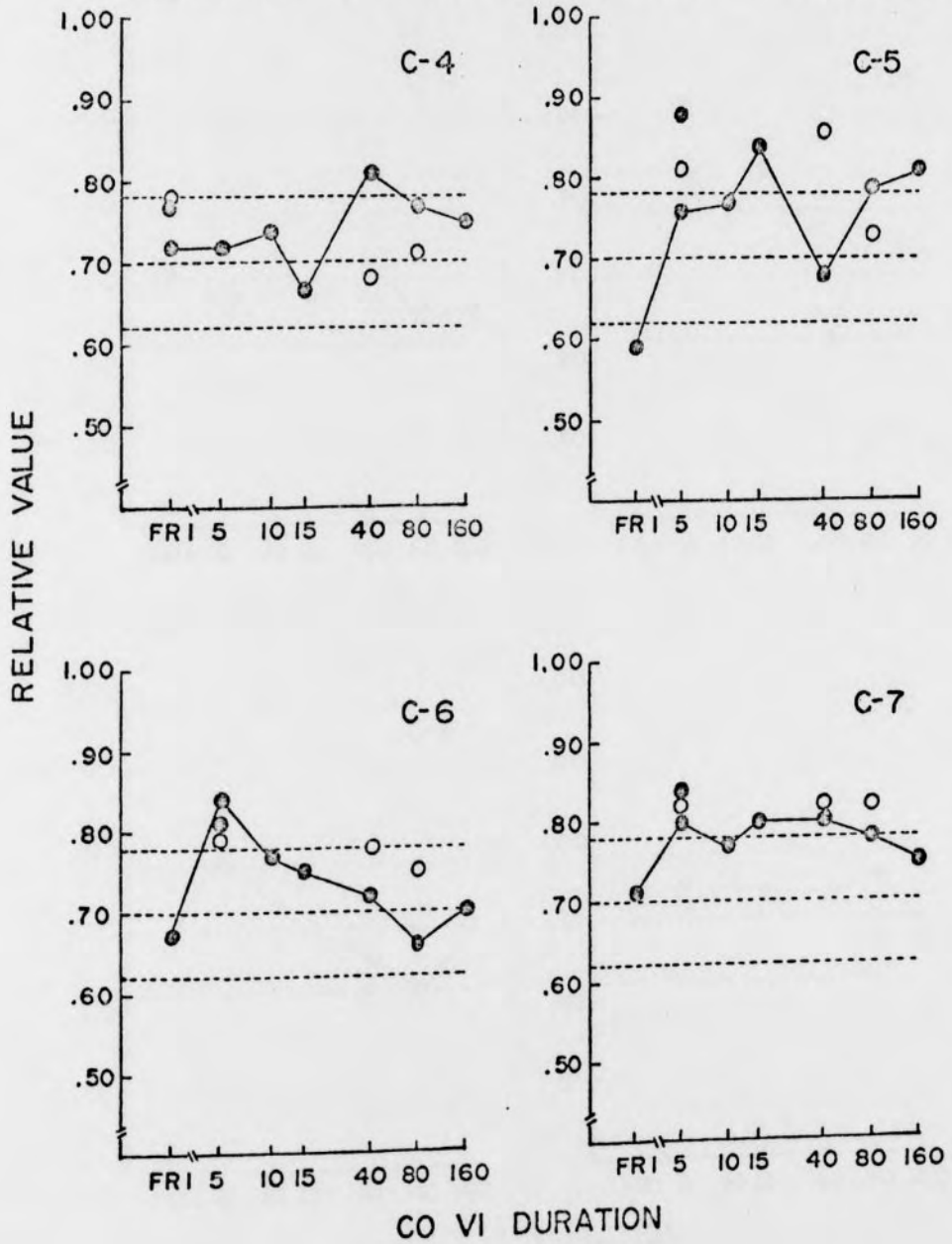
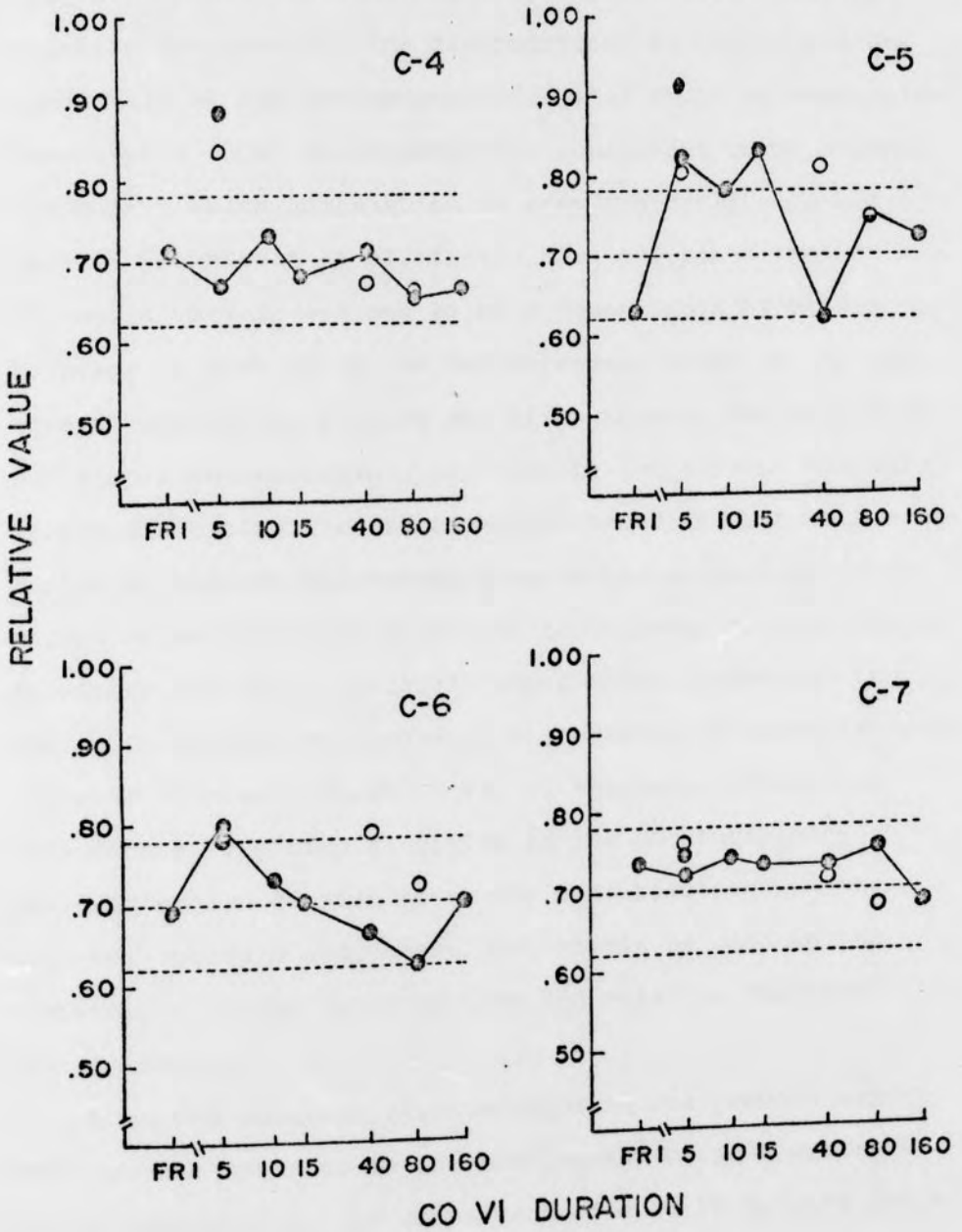


FIGURE 9

MAIN-KEY AND CO-KEY RELATIVE TIME



considering the effects of a COD, FR, or VI CO contingency, the inclusion or exclusion of the behavior during the contingency does affect the shape of the function relating relative response or time distributions to the CO contingency values, but the general effect of these contingencies does appear to be consistent when consistent computations are made. Which computation is more appropriate is not clear. Brownstein et al. (1972) have suggested that if the CO contingency is assumed to be a determinant of choice behavior as much so as the reinforcement rates of the concurrent schedules, then at any given moment, the choice is not simply between allocating time to the current schedule versus allocating time to the other schedule, but rather the choice is between allocating time to the current schedule versus allocating time to the CO contingency in addition to the other schedule. Thus, in the present procedure, the choice is whether to remain in the current VI schedule or to allocate time to a Chain CO VI, VI schedule. Viewed in this manner, the time allocated to the CO contingency reflects choice as much so as the time allocated to the main-key schedule and, therefore, should be used in the computation of the relative time and relative response distributions.

That the obtained relationships in the present experiment are not specific to the contingency being a variable one is suggested by the comparison of a CO FI 3.5 sec and a

CO VI 5 sec, which showed that these two contingencies produce approximately comparable effects as indicated in each figure. Similarity in the effects of these two contingencies is most apparent in the CO rates in Figures 4 and 5.

Shull and Pliskoff (1967) have suggested that the matching of relative responses to relative reinforcement rate may be a by-product of the matching of relative time to relative reinforcement rate. Several experiments have supported this suggestion. Brownstein and Pliskoff (1968) showed that in an arrangement in which there was no main-key and responses on a CO-key alternated the illumination of the chamber, birds partitioned their time in proportion to the relative reinforcement rate. The same relation has been observed in a shuttle-box arrangement in which no explicit CO operant was required and the pigeons moved from one side of the box to the other (Baum and Rachlin, 1969). If the response distribution is, in fact, a by-product of the time distribution, the two distributions must be isomorphic; that is, responding must occur at equal local rates. Figures 1 and 2 show that when the CO VI was varied, this isomorphism did not occur and consequently, the relative local rate, depicted in Figure 3, increased since the response distribution deviated more from matching than did the time distribution. Similar changes in relative local response rates occur when shock, TO and FR contingencies are varied. Mathematically, when non-matching occurs, local

response rates could, in fact, not change; that is, they would remain at 0.50 providing that the response and time distributions remained isomorphic. However, this is not what has been reported to have occurred when non-matching has occurred. Instead, while both distributions change, they are not isomorphic, indicating that local rates are changing. With regard to the use of a shock contingency, Todorov (1971) has viewed relative responses, as determined not solely by the time distribution, but rather as determined by the time distribution and local response rates. Changes in local rates, according to Todorov's analysis, are determined jointly by the relative reinforcement rate and the shock contingency so that as a result of the shock contingency, the stay-times in each schedule increases resulting in the development of control of responding by the reinforcement rates of the two separate schedules. Thus, when the relative reinforcement rates are 0.50, the local response rates would not change since each schedule would control the same response rate. But, when the reinforcement rates are unequal, the local response rates are controlled more and more by the individual reinforcement rates. Computation of the local rates from Table 1 reveals that the rates in green tended to increase and the rates in red tended to decrease as a function of the CO VI, thus supporting Todorov's analysis of local response rates.

Figures 4 and 5 show that both CO operants are decreasing functions of the CO VI. This indicated that as the CO VI increased, there was an increase in the latency of both the CO operants and thus, an increase in the main-key stay-times. Whether the increase in latency of the CO operants resulted in the increase in the main-key stay-time, or whether the increase in main-key stay-times resulted in the increase in the latency of the CO operants is perhaps an unresolvable issue, but, nevertheless, represents two models, the CO model and the time allocation model, both of which are attempts at accounting for the relationship between CO behavior and main-key behavior. Each assumes that the main-key response distributions are determined by the time distributions, but they differ in accounting for the nature of the causal relation between CO rates and main-key time distributions. According to the CO model as presented by Shull and Pliskoff (1967) with regard to the COD, the COD, in conjunction with relative reinforcement rate, determines the frequency of the CO operants since their ratios simplify to the relative time distribution. This view that the time distribution results indirectly from the CO behavior is a likely view to entertain, given the distinction made between CO and main-key operants and also because the CO contingency follows the CO operants temporally.

While the CO model suggests that both the main-key reinforcement rates and the CO contingency determine the CO rate, the time allocation model suggests that these factors act directly on the allocation of time which then determines the CO distribution as well as the main-key response distribution. That is, the CO model assumes the main-key responses to be determined by the allocation of time, but assumes the allocation of time to be determined by the CO behavior so that the locus of the effect of varying reinforcement rates and CO contingencies is on the CO operants. On the other hand, the time allocation model assumes that responses, whether CO or main-key are both determined by the allocation of time. The locus of the effect of varying reinforcement rates and CO contingencies, according to this view, then, is in the duration of one behavior relative to the duration of another behavior.

This latter point of view has been put forth explicitly by Baum and Rachlin (1969) and Rachlin (1971) who have suggested that the various reinforcement parameters, such as delay, amount and rate, interact multiplicatively to determine the reinforcement value for any two activities. Time will be allocated then, so that the ratio of the value of the two activities is as follows:

$$T_1/T_2 = R_1/R_2 \cdot A_1/A_2 \cdot I_1/I_2 \cdot X_1/X_2 = V_1/V_2,$$

where $\underline{T}$ represents the time spent engaging in each of the two activities, $\underline{V}$ represents the value of the two

activities, and the reinforcement parameters are rate (R), amount (A) and immediacy (I) and X is a parameter other than rate, amount and immediacy. As Rachlin (1971) has pointed out, this equation is not an empirical law, but rather a definitional statement of how to measure the reinforcement value of two events. He argued that the value of such a law that is tautologous rather than empirical is that it tells one where to look when apparent discrepancies occur. With regard to the present concern with the effects of CO contingencies on concurrent performance, the value formulation would suggest that when imposing a CO contingency or changing the value of a current CO contingency changes the relative time distribution, this would not refute the matching law, but rather suggest that either a new input has been entered into the value formula, or that some variable has changed the value of one of the value parameters already in effect so that the contribution of the prior reinforcement parameters is altered by the new input so as to yield a new value ratio which would be reflected by the changed time distribution ratio. By definition, then, non-matching never occurs. The use of the term merely reflects that all the value parameters have not been identified.

Lander and Irwin (1968) have provided a model whereby the ratio of responses, when plotted as a function of the ratio of reinforcements, yields a family of curves of the

equation $N_1/N_2 = (n_1/n_2)^a$ where N and n, respectively, represent the number of responses and number of reinforcements in each component and a is a parameter which "may be regarded as indicative of the sensitivity of the distribution of responses between components to the distribution of reinforcements between these components [p. 523]." According to Rachlin's value formulation, number or frequency of reinforcement is only one of the reinforcement parameters whose ratios multiplicatively yield a ratio of reinforcement value for the two events. How value is affected by CO contingencies has not been set forth. Since the ratio of a CO contingency reduces to unity when the CO contingency is the same for each schedule, the ratio of the numerical values of the CO contingency does not merely combine multiplicatively with other reinforcement parameters. Possibly, the value of the CO contingency enters into the determination of a. A simple manner in which the CO contingency could contribute to a is as follows: $a = f(CO_x/CO_m)$, where m represents the value at which a given CO contingency generates matching and x represents any given value of that CO contingency. Thus when $x = m$, $a = 1$ and matching would occur, provided that other determinants of a also reduce to unity.

Regardless of whether one favors a model of choice behavior based on the allocation of time or based on CO rates, why a decrease in CO rates occurs at all must be

considered. Mathematically, it is possible to obtain differing time distributions without changing the overall CO rate. All that is required is that the local CO rates be differential. One account, which is implicit in the assumption that the rapid alternation that often occurs between concurrent schedules is due to concurrent superstition, is that the decrease in CO rates is due to systematically increasing a delay between the CO response and reinforcement. This could easily be extended to account for the rate decrease with VI, TO and FR contingencies since the VI and TO are also temporal contingencies and the FR contains a temporal component. However, it is difficult for the concurrent superstition notion to account for the CO rate decrease when a non-temporal contingency like shock is placed on the CO response. It is possible that the concurrent superstition notion may adequately account for the development of high CO rates, but that a decrease in CO rates may or may not be due to preventing temporal correlation of responses on one key and reinforcement on the other.

In accounting for decreasing CO rates as a function of the COD, Pliskoff (1972) has identified a dual role for the COD. The first effect is that of forcing the animal to "wait out the delay" so as to collect all the reinforcements. The effect could be extended to the use of TO, FR and VI contingencies since although these contingencies are not on the main-key, they nevertheless represent temporal

delays that must be fulfilled before reinforcement is available. This effect could not be extended to the use of shock, however, since the first response after a CO can be reinforced. The second role of the COD that Pliskoff identifies is that of functionally punishing the CO response. This punishing role can easily be extended to other CO contingencies since shock is well established as a punisher and since TO, FR and VI contingencies all represent time-out from positive reinforcement.

Implicit in both the concurrent superstition account and Pliskoff's account is the notion that CO contingencies affect the strength of the CO operants. If, however, a distinction is not made between CO and main-key operants, and instead all the behavior is viewed as main-key behavior, then another account of the decrease in CO rate is available. Viewing the CO contingency as a choice parameter, the CO contingency might be conceptualized as the first member of a chain or tandem schedule, depending upon the particular CO contingency. Increasing the value of the CO contingency, then, would serve to make the overall reinforcement value of the concurrent schedules more discrepant so that the stay-time in the two schedules would be expected to differentially increase, thus resulting in decreasing CO rates.

The present procedure was different from usual concurrent procedures in that it permitted a measure of CO behavior while changing over was occurring. Catania (1966)

has suggested that because the CO operants do not produce reinforcement, but only change the schedule stimuli, the schedule stimuli are established as conditioned reinforcers maintaining the CO operants. Thus, the main-key schedule would serve as the terminal links and the CO operants would represent FR 1 initial links. Autor (1960) has shown in a concurrent chain schedule in which the initial links were concurrently available and the terminal links were mutually exclusive, that the relative response rate in the initial links matched the relative rates of reinforcement in the terminal links. The present procedure, then, represents a modified CO-key concurrent chain procedure. Figures 6 and 7 show that the response rates on the CO-key were a decreasing function of the CO VI, but that, with the exception of C-4, the relative response rates did not deviate appreciably from 0.50 even when the colors of the initial links were changed. Why matching of initial links responses to the terminal link reinforcement rates did not occur is not immediately clear. However, the present procedure differs from the usual concurrent chain procedure in two major respects. First, the initial links, instead of being associated with two different concurrently available key, are represented by the CO-key so that the initial links are not concurrently available, but are mutually exclusive. In the usual concurrent chain procedure, choice responses can occur freely in both initial links until entry is gained in the

terminal links. In the present procedure, there is essentially only one choice response and it is the first one that occurs on the CO-key following a main-key response. The subsequent responses do not represent choice responses because in a sense, the bird is already in the terminal schedule since the CO VI must be completed and one main-key response be made before another CO can be initiated.

The second procedural difference between the present procedure and the usual concurrent chain is that in the latter, exit from the terminal link and therefore, entrance into the initial links is only via reinforcement. In the present procedure, exit from the terminal link was not related to reinforcement in terms of programming. This reversibility of the links allowed the actual number of links preceding the terminal one to become very long. Fantino and Duncan (1972) have demonstrated that the chaining operation does, in fact, reduce preference in concurrent chains. Either of these two programming features, or perhaps both, could possibly account for not finding matching of relative CO-key response rates to main-key reinforcement rates.

In the present study, the relative time distributions may not accurately reflect the relative reinforcement value of the two schedules since reinforcement programmed for one schedule had to be obtained before reinforcement would be programmed for the other schedule. Such a

procedure actually forces the bird to spend a minimum amount of time in the leaner schedule. Inspection of Table 1 shows that the session time in green tended to increase across CO VIs, but that session time in red was relatively constant. Possibly, the effect of even the lowest CO VI on the reinforcement value of the leaner schedule was great enough that the time in red was due to this programming of reinforcements rather than the value of the schedule. It was not possible to determine how much of the relative stay-time was due to forcing COs in order to receive successive reinforcements.

CHAPTER V

SUMMARY

Previous studies using concurrent variable-interval schedules of reinforcement have indicated that the relative response and relative time distributions approximate or match the relative reinforcement distribution across a wide range of COD values. In the present experiment a variable-interval contingency imposed on the changeover resulted in large discrepancies from matching. However, when computation of the relative response and relative time distributions included the CO-key behavior, more of the points in these distributions fell within the matching range.

Matching of relative responses on the CO-key to the main-key reinforcement rates did not occur as could have been expected since the present procedure may be considered as concurrent chain procedure. Programming differences in the present procedure and the usual procedure may be responsible.

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